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TESTS OF BIOLOGICAL INTEGRITY IN DOGS EXPOSED TO AN ELECTROMAGN--ETC(U)  
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**TESTS OF BIOLOGICAL INTEGRITY  
IN DOGS EXPOSED TO AN  
ELECTROMAGNETIC PULSE ENVIRONMENT**

S. J. Baum

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Research was conducted according to the principles enunciated in the "Guide for the Care and Use of Laboratory Animals," prepared by the Institute of Laboratory Animal Resources, National Research Council.



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REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER AFRRI SR78-2	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) TESTS OF BIOLOGICAL INTEGRITY IN DOGS EXPOSED TO AN ELECTROMAGNETIC PULSE ENVIRONMENT		5. TYPE OF REPORT & PERIOD COVERED
7. AUTHOR(s) Siegmond J. Baum		6. PERFORMING ORG. REPORT NUMBER
9. PERFORMING ORGANIZATION NAME AND ADDRESS Armed Forces Radiobiology Research Institute (AFRRI) Defense Nuclear Agency Bethesda, Maryland 20014		8. CONTRACT OR GRANT NUMBER(s)
11. CONTROLLING OFFICE NAME AND ADDRESS Director Defense Nuclear Agency (DNA) Washington, D. C. 20305		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS NWED QAXM F 101 06
14. MONITORING AGENCY NAME & ADDRESS (If different from Controlling Office)		12. REPORT DATE August 1978
		13. NUMBER OF PAGES 13
		15. SECURITY CLASS. (of this report) UNCLASSIFIED
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE
16. DISTRIBUTION STATEMENT (of this Report)  Approved for public release; distribution unlimited		
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)		
18. SUPPLEMENTARY NOTES		
19. KEY WORDS (Continue on reverse side if necessary and identify by block number)		
20. ABSTRACT (Continue on reverse side if necessary and identify by block number) Dogs were exposed to an electromagnetic pulse (EMP) environment 8 hours each day for 45 days. At the end of that time they had received $5.8 \times 10^6$ EMP at 5 pulses/sec with a peak electric field intensity of 447 kV/m. Biological tests were conducted to ascertain concentration of erythrocytes, leukocytes, neutrophils, lymphocytes, reticulocytes, and platelets. Bone marrow samples were obtained by biopsy from the ribs 7 days before and 7 days after the last EMP exposure for assessment of mitotic rubricytes and myelocytes. Pregnant female dogs were exposed to the EMP environment in order to study possible gross effects		

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20. ABSTRACT (continued)

on fetuses. Reproductive capabilities of irradiated male animals were tested for 1 year after the last exposure. None of these tests revealed any injury in the EMP-irradiated dogs.

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## INTRODUCTION

The short, intense electromagnetic pulse (EMP) produced by high-altitude nuclear explosions may radiate over many hundreds of miles. Since such pulses can induce large voltages and currents in conductors, some cables and electronic test equipment in early nuclear weapons testing were upset or damaged by the EMP energy. Simulators of EMP environments were constructed to study these effects, and they presented a potential hazard to personnel conducting the tests. However, early analysis indicated that for a body insulated from the ground, current flow and thermal heating do not pose a hazardous condition (1). The possibility existed, however, that at the molecular level in biological systems, there were vital ionic and electrochemical processes that could be altered by rapid pulses of electric and magnetic fields. Potentially, such altered processes could affect acutely biological systems with high cellular turnover (2).

However, results obtained from experimental studies conducted at the Armed Forces Radiobiology Research Institute (AFRRI) clearly indicated that rodents exposed continuously for 94 weeks of their adult lives to a total of  $2.5 \times 10^8$  pulses from an EMP simulator sustained no detectable injuries (2,3). Each animal was subjected to 5 pulses/sec at peak electric field of 447 kV/m; each was insulated from the ground to prevent current flow into or out of the body. This exposure condition was considerably in excess of that normally encountered by workers operating EMP facilities (4). The biological tests involved parameters from systems of high cellular turnover (such as the hematopoietic and reproductive systems) and from tumor inducers. Partly based on these negative findings, the Occupational Safety and Health Administration (Department of Labor) decided that a proposed standard on human exposure to electromagnetic pulses should not be issued (5). However, since the geometrical differences between a small rodent and man are rather large, it is possible that physical and/or physiological changes could be induced by EMP in man that might not have been observable in the much smaller rat or mouse. Therefore, the selection of a larger mammal with a hematopoietic system similar to man was indicated. The animal of choice was the dog because of the similarity of its blood cell production to that of man and the availability of accurate data for normal animals (6-8). Furthermore, it is known that many human diseases have a canine equivalent (9). The present experiment was designed to measure the acute effects of EMP exposure on the hematopoietic system and on some aspects of the reproductive system of a few dogs in order to compare with results obtained earlier in rats.

## METHODS

Healthy, purebred, AKC-registrable, male and female beagles, 1-2 years old, ranging from 9 to 13 kg, were obtained from the AFRRI colony for use in this study. They were under a veterinarian's care for prevention of parasitic infestation and were immunized against distemper, hepatitis, and rabies.



Before the experiment and when not being exposed to the EMP or sham environment, the dogs were housed individually in stainless steel cages of officially approved size in temperature-controlled rooms. Approximately 65 days after the first EMP exposure, the dogs were boarded at the colony of Richard E. Saunders, Inc., Richmond, VA. There the dogs were housed in larger cages and were given adequate space for exercise. The animals were fed kibbled laboratory dog food daily, supplemented once a week with a high-protein, canned-meat ration. Water was available ad libitum.

A total of 26 dogs were used in this study; 9 (4 males, 5 females) were exposed to the simulated EMP environment and 9 (4 males, 5 females) served as sham-irradiated controls. Four pregnant female dogs were exposed to the EMP environment between days 10 and 55 of gestation to measure possible radiation effects on the fetuses; 4 nonexposed pregnant female dogs served as controls. The animals were exposed to the EMP environment 8 hours each day for 45 days. At the end of that time they had received approximately  $5.8 \times 10^6$  EMP.

Blood samples were obtained via jugular vein 1 week before exposure, thereafter every week during the 45-day exposure period, and for 3 weeks thereafter. Final blood samples were obtained 1 year after the last EMP exposure. The concentrations of erythrocytes, leukocytes, neutrophils, lymphocytes, reticulocytes, and platelets were routinely determined in  $1 \text{ mm}^3$  of blood. Bone marrow samples were obtained by biopsy from the ribs 7 days before and 7 days after the last EMP exposure. For this procedure the dogs were anesthetized with Nembutal sodium solution at a concentration of 30 mg/kg, injected intravenously. The fraction of mitotic rubricytes and myelocytes was determined.

The AFRRI EMP generator used in this study has been described previously in detail. It provided 5 pulses per sec with a peak electric field intensity of 447 kV/m with a 5-nsec rise time and a 550-nsec  $1/e$  fall time (1). The pulse generator fed a parallel plate transmission line structure that permitted the placement of five nonmetallic dog cages between the plates to prevent current flow into or out of the dog body.

Student's "t" test was used to determine the significance of differences between groups.

## RESULTS

A comparison of concentrations of the circulating erythrocytes and reticulocytes clearly indicates that exposure to electromagnetic pulses had no injurious effects (Figures 1 and 2). The number of peripheral leukocytes, neutrophils, and lymphocytes of irradiated dogs was similar to that of nonirradiated control animals (Figures 3-5). No changes were observed in the concentration of platelets (Figure 6). One year after the last EMP exposure, blood values were obtained

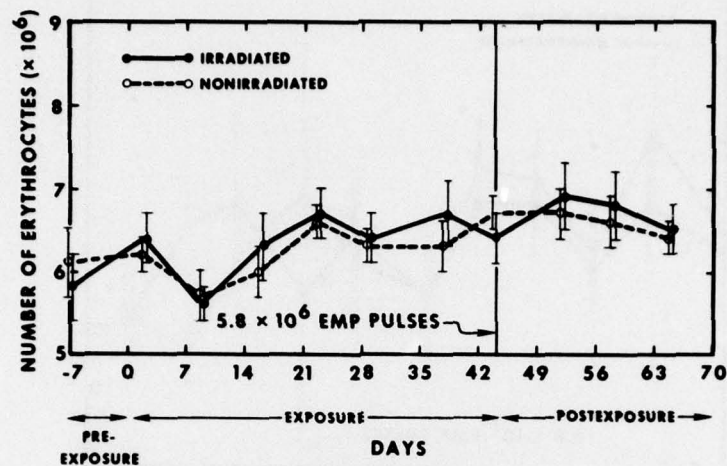


Figure 1. Erythrocyte concentration per  $\text{mm}^3$  of blood in dogs exposed to an EMP environment 8 hours per day for 45 days. Each point shows a mean value with the associated standard error.

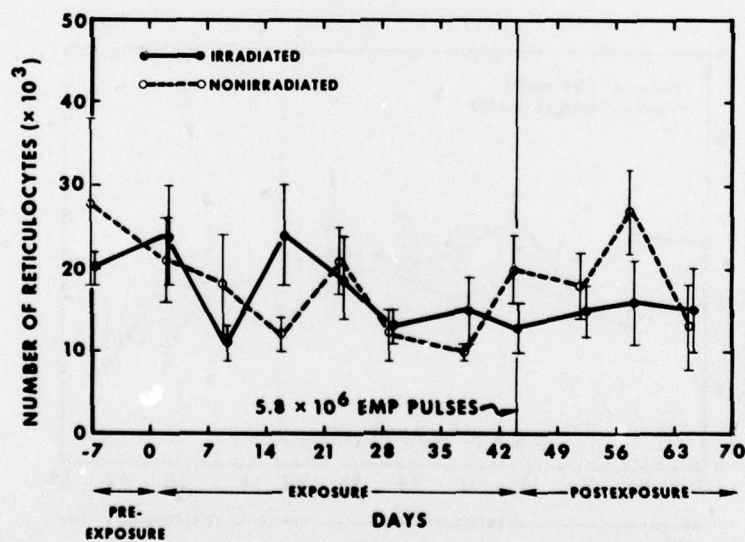


Figure 2. Concentration of circulatory reticulocytes per  $\text{mm}^3$  of blood in dogs exposed to an EMP environment 8 hours per day for 45 days. Each point shows a mean value with the associated standard error.



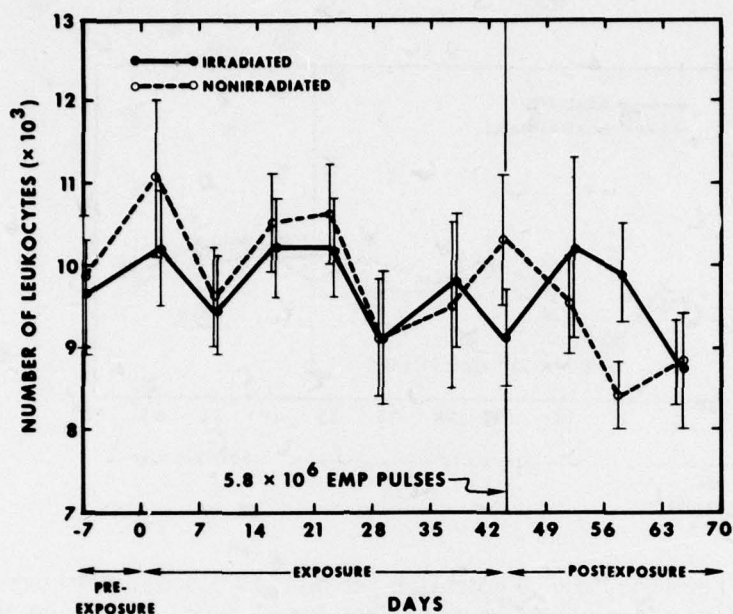


Figure 3. Number of leukocytes per  $\text{mm}^3$  of blood in dogs exposed to an EMP environment 8 hours per day for 45 days. Each point shows a mean value with the associated standard error.

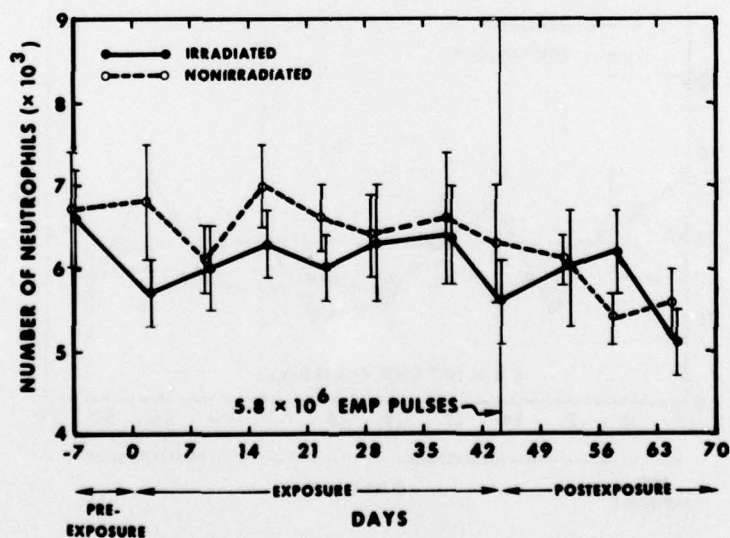


Figure 4. Number of neutrophils per  $\text{mm}^3$  of blood in dogs exposed to an EMP environment 8 hours per day for 45 days. Each point shows a mean value with the associated standard error.

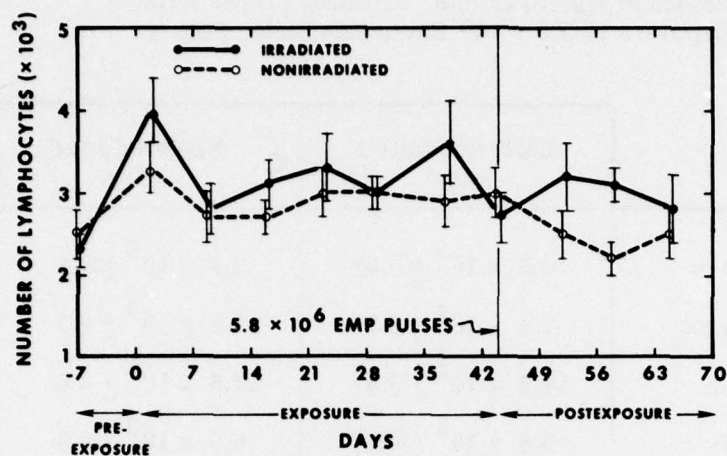


Figure 5. Concentration of circulating lymphocytes per  $\text{mm}^3$  of blood in dogs exposed to an EMP environment 8 hours per day for 45 days. Each point shows a mean value with the associated standard error.

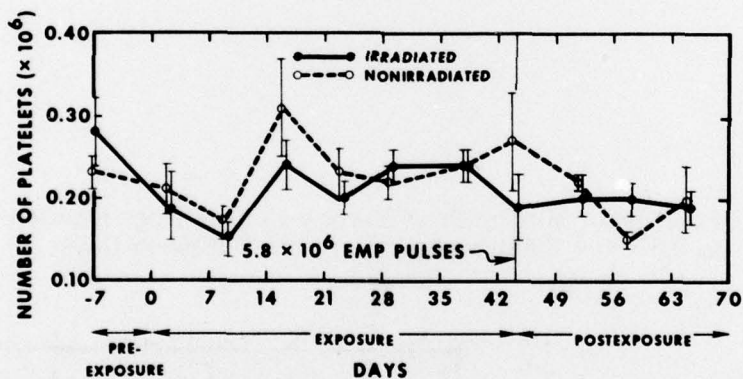


Figure 6. Platelet concentration per  $\text{mm}^3$  of blood in dogs exposed to an EMP environment 8 hours per day for 45 days. Each point shows a mean value with the associated standard error.

from the same dogs and again no differences were observed (Table I). Seven days before irradiation, the percentage of mitotic erythrocytic and myelocytic bone marrow cells was determined in all dogs. These values did not differ significantly from those obtained in similar determinations 7 days after the last exposure (Table II).

Table I. Values of Cells Per mm<sup>3</sup> of Blood 1 Year After Exposure to  $5.8 \times 10^6$  Electromagnetic Pulses

	EMP-irradiated dogs	Nonirradiated dogs
Erythrocytes	$6.1 \times 10^6 \pm 0.3^*$	$5.9 \times 10^6 \pm 0.4$
Reticulocytes	$2.1 \times 10^4 \pm 0.5$	$2.2 \times 10^4 \pm 0.3$
Leukocytes	$10.4 \times 10^3 \pm 0.5$	$10.6 \times 10^3 \pm 0.6$
Neutrophils	$6.8 \times 10^3 \pm 0.4$	$6.9 \times 10^3 \pm 0.3$
Lymphocytes	$2.4 \times 10^3 \pm 0.3$	$2.5 \times 10^3 \pm 0.2$
Platelets	$3.5 \times 10^5 \pm 0.2$	$3.6 \times 10^5 \pm 0.3$

\* Standard error of the mean

Table II. Fraction of Mitotic Bone Marrow Cells in Dogs Exposed to  $5.8 \times 10^6$  Electromagnetic Pulses During 45 Days

	Mitotic rubricytes	Mitotic myelocytes
7 days before EMP exposure	$0.025 \pm 0.005^*$	$0.013 \pm 0.004$
7 days after last exposure	$0.026 \pm 0.003$	$0.011 \pm 0.003$

\* Standard error of the mean



All dogs were under continued care of a veterinarian, who performed routine examinations periodically. At no time were any damaging effects observed in the animals exposed to the electromagnetic environment. The litters of the four irradiated pregnant female dogs were similar in size (four to six pups per litter) to those of the four nonirradiated control animals. All pups were clinically normal. On return to the dog colony in Richmond, VA, the four EMP-exposed male dogs and their four nonexposed controls were mated with normal female beagles from the colony. In all cases, sizes of litters were normal (five to six pups) and indicated no differences in mating capabilities between the irradiated and nonirradiated male beagles. Veterinary examinations of the pups disclosed no abnormalities in the newborn dogs sired by previously irradiated male beagles.

### DISCUSSION

The previously reported studies using rodents (2,3) were designed to determine the possibility of biological injury from exposure to an EMP environment under maximum adverse conditions. These conditions were considerably in excess of those normally encountered by workers who operate EMP facilities (2,4). No biological damage was observed under these conditions for rats and mice.

The dog experiment was designed to simulate more closely personnel exposure to EMP for approximately 8 hours per day for about 6 weeks. Nevertheless, the physical exposure parameters were still in considerable excess of those normally encountered by workers in EMP-stimulated environments. The biological parameters studied in the dogs were similar to those observed earlier in rats (2,3). However, the production, distribution, and function of the hematological cells in dogs are more similar to those of man. The absence of any deleterious effects observed in dogs exposed to the EMP environment allows the assumption with much greater confidence that man similarly faces no hazards under these conditions.

### ACKNOWLEDGMENTS

The author is thankful for the superb veterinary care and evaluation of Dr. Stephen Clarkson. The competent and diligent technical assistance of J. L. Atkinson and R. T. Brandenburg is greatly appreciated.

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